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NATIONAL BUREAU OF STANDARDS REPORT

2531

PROGRESS REPORT
for
Dec. 1, 1952 to April 30, 1953

on

GREASE FILTER TEST METHODS

by

C. W. Coblentz
P. R. Achenbach

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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1003-20-4715 May 29, 1953 2531

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GREASE FILTER TEST METHODS

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C. W. Coblentz
P. R. Achenbach
Heating and Air Conditioning Section
Building Technology Division

for

Bureau of Ships
Department of the Navy
Washington, D. C.

NBS

Progress Report
Dec. 1, 1952 to April 30, 1953
on
GREASE FILTER TEST METHODS
LOADING RATES OBSERVED ON U.S.S. TARAWA

The examination of the grease deposits from the air samples taken in the crew's galley of the U. S. S. Tarawa has shown that the grease content of the air varied widely during the frying operations. Samples were taken on filter paper, in sampling tubes filled with glass wool, and on microscopic slides by means of an impactor. In all cases, the sampling was done about half way between the respective cooking facility and the nearest filter by drawing a measured volume of air through the sampling device. The weight increases of the sampling tubes and the filter papers were determined by weighing them to the nearest 0.1 mg before and after the test, the sampler having been thoroughly dried in a desiccator before each weighing. The grease samples collected on microscopic slides on the U. S. S. Tarawa were compared as to their density with deposits from equal air volumes of known grease content in the grease filter test apparatus at the National Bureau of Standards. These comparisons confirmed the data obtained with the two other sampling methods used on the U. S. S. Tarawa.

Fig. 1 is a 450 x magnification of a grease deposit obtained during the frying of steaks on the griddle on board ship. The particles range from the limit of resolution of the microscope to relatively few of fifty microns diameter or more.

Fig. 2 is a microphotograph of the same magnification of grease accumulated on the surface of one of the filters above the deep fat fryers. The range of the particle size is approximately the same as in Fig. 1. It will, however, be noticed that there are relatively more big particles in Fig. 2 than in Fig. 1 and fewer small particles in Fig. 2 than in Fig. 1. This is believed due to the fact that a larger percentage of the bigger particles is retained on the filter face than of the small ones. The agglomeration of grease particles around the cotton fiber in Fig. 2 indicates that difficulty in cleaning the filters might occur when these fibers are wedged into the filter media.

Fig. 1

Fig. 2

Fig. 3 is a microphotograph with the same magnification of grease deposits taken from the duct behind the filter above the deep fat fryer. The range of the particle size, again, is about the same; this time, however, the proportion of bigger particles is very much smaller. There are few agglomerations and little adhesion of the particles to the fiber fragments in Fig. 3.

The following table shows the average values of the grease content of the air computed from the samples taken with filter paper and glass wool samplers for different frying operations on the U. S. S. Tarawa. Also shown are the equivalent loading rates for a 20 x 20 in. filter as determined in the grease filter test apparatus. The filtering efficiency measured on a Farr #4 filter in the grease filter test apparatus is shown in the table for each loading rate and corresponding grease content as observed on board ship. The results reported on the Farr #4 filter are representative of the impingement filters most used. The deviation in the efficiencies of other similar filters at the observed grease contents of the air are small.

Frying Operation	Grease Content of Air mg/ft^3	Equivalent Loading Rate of 20x20 in. Filter g/hr	Observed Efficiency of Farr Filter in Laboratory %
Steak on Griddle	1.78	92	90
Fish in Deep Fat Fryer	0.87	42	84
Potatoes on Griddle	0.42	19	79
Corn Fritters in Fryer	0.22	9	75

The values indicate a wide range of loading rates depending on the kind of cooking operation. It can be expected that the loading rates would vary in excess of ±100% at different times due to temperature of the grease and depending on the ventilation rate just above the ranges. The lowest efficiency observed in the laboratory corresponding to the grease contents observed on the U. S. S. Tarawa was 75% and it increased to 90% at the highest grease concentration in the air.

Out of a group of 13 filters taken from several Navy vessels that were tested here in the early part of 1951, the most heavily loaded grease filter of the group was used in the hood above the griddles on the U. S. S. Coral Sea. This filter was said to have been in continuous operation for four

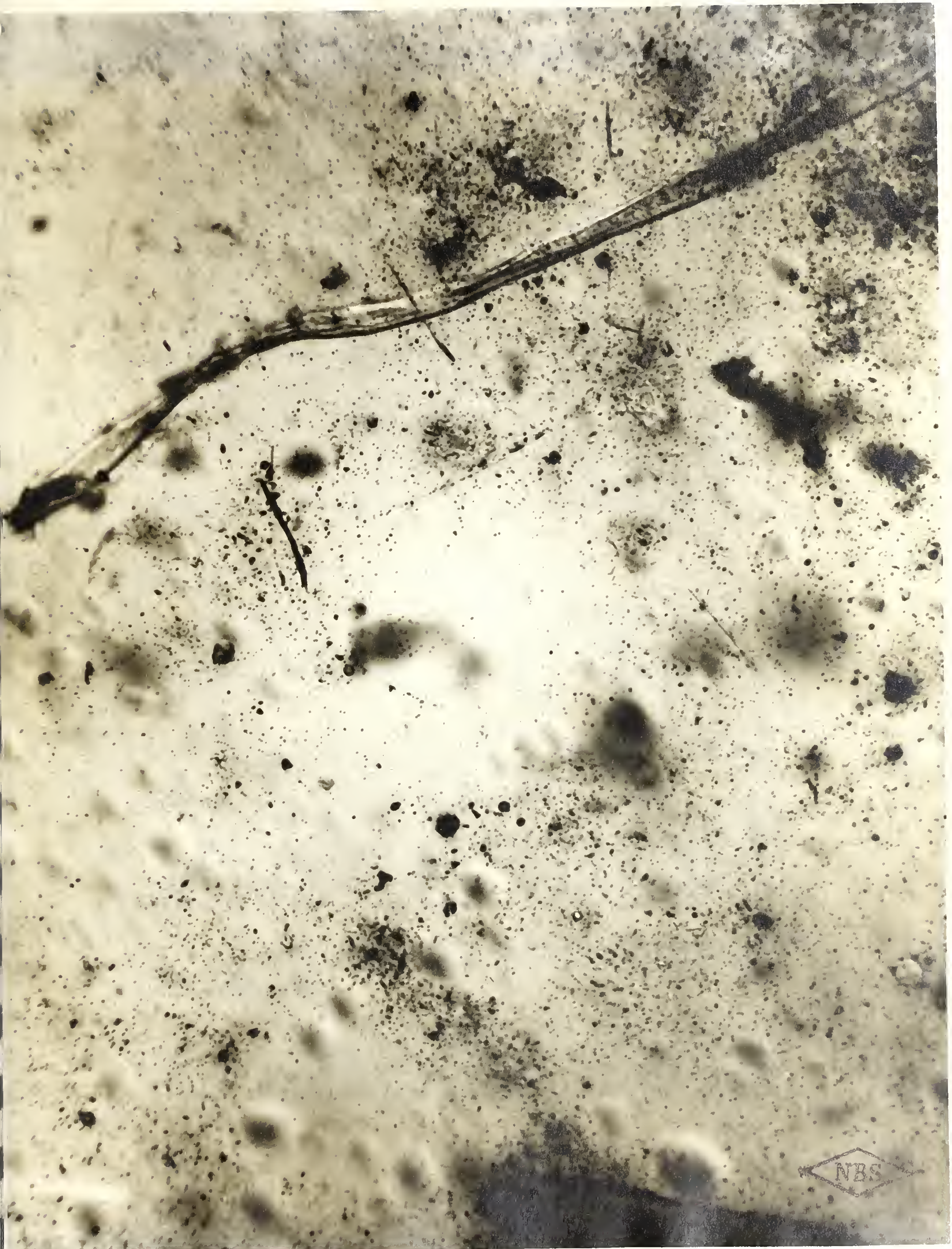


Fig. 3

weeks at a face velocity of 468 fpm and was found to contain a total load of 2.27 oz, equivalent to 70 grams on a 20 x 20 in. filter. An analysis of the deposits showed that 37%, or about 26 grams, of the filtrate was fat. Assuming that all fat had been collected on this filter during a one hour daily operation of the griddles, an average loading rate of less than 1 gram per hour would be indicated for this kind of operation.

However, actual tests made over griddles on board the U. S. S. Tarawa showed loading rates as high as 92 g/hr at conditions which should be similar to those on the U. S. S. Coral Sea. Considering that some additional grease was probably being collected in the filter on the U. S. S. Coral Sea during the estimated 23 hours of the day when there was no frying done on the griddles, there is a ratio of approximately 1 to 100 between the loading rates for the two ships. In our opinion there probably was not actually that much difference in the loading rates during similar operations in the two installations.

Efficiency Tests at 800 ft/min Face Velocity

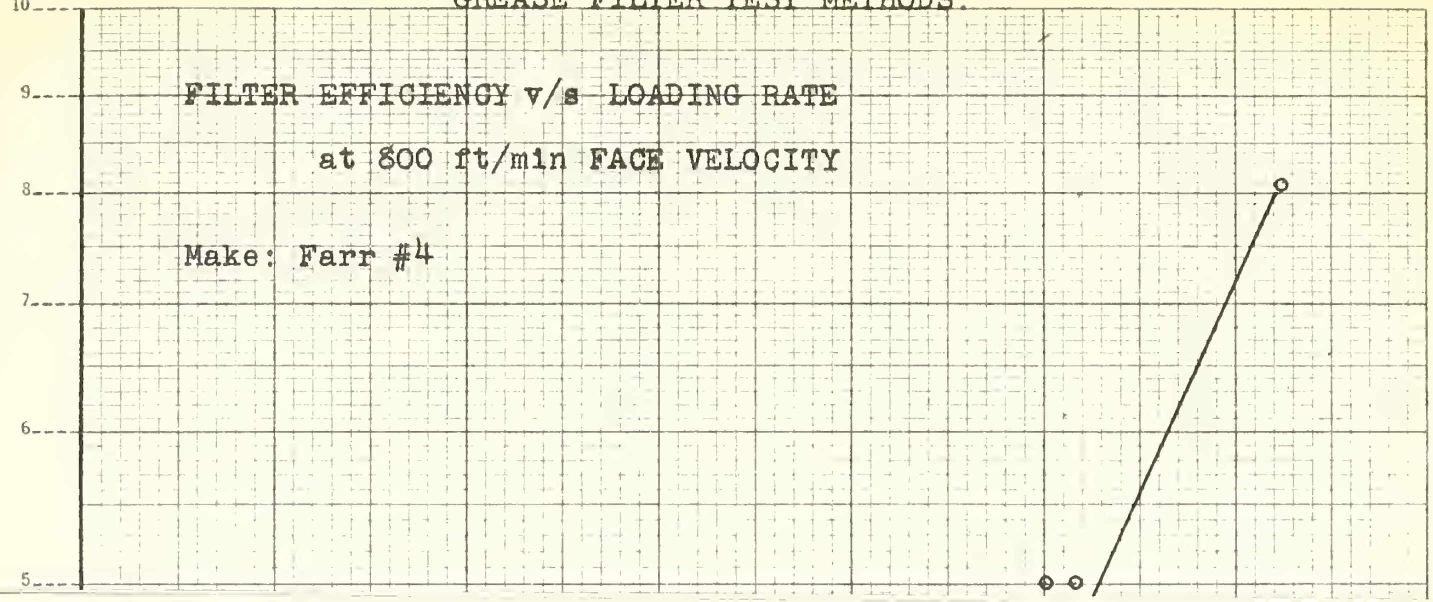
A series of 70 tests was made to determine the efficiency of grease filters operating at 800 ft/min face velocity. Based upon the information obtained about the loading rates to be expected in actual operation from the above described sources all these tests were conducted at loading rates below 10 g/hr.

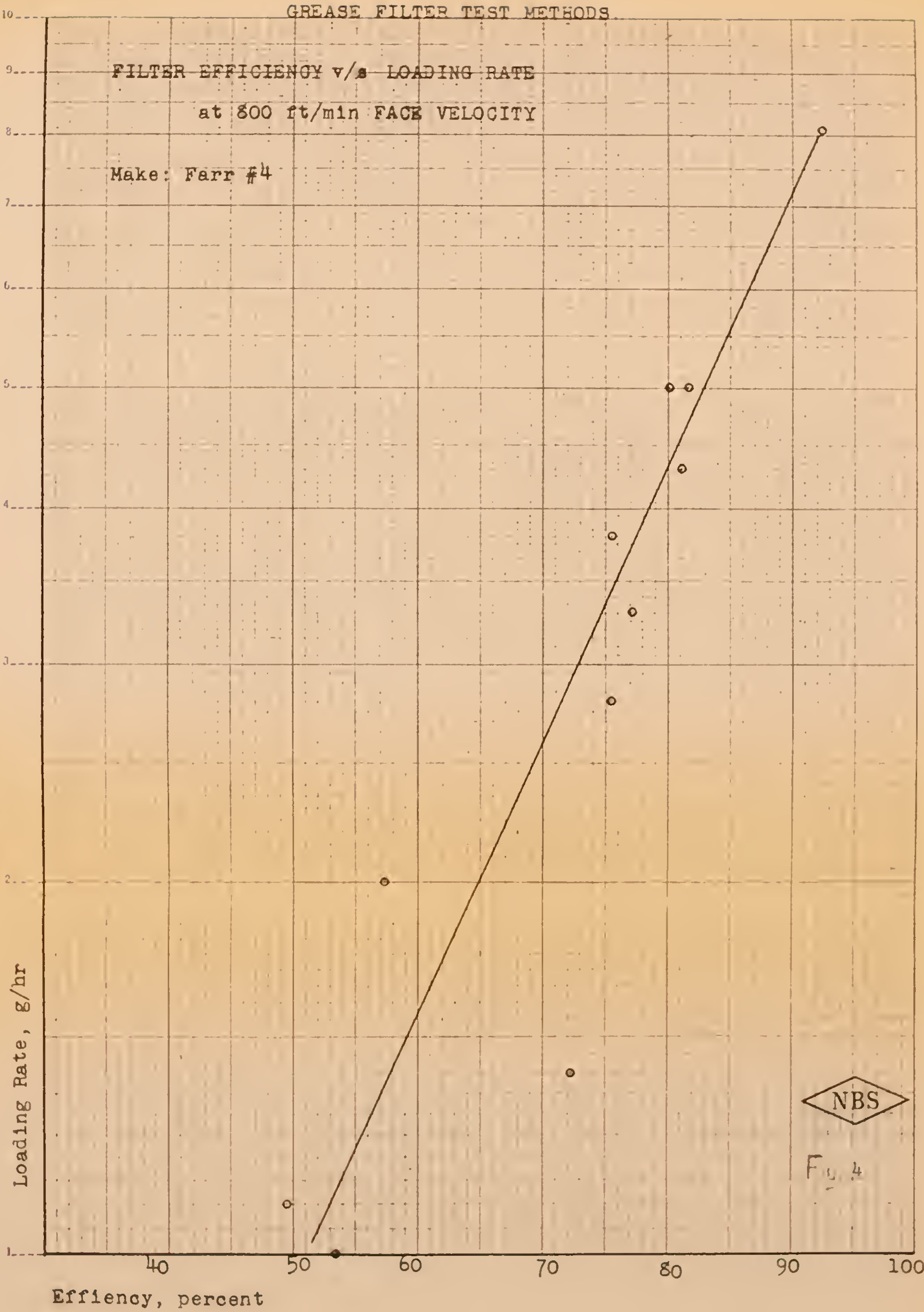
The grease filter test apparatus was originally equipped for handling air flow rates up to 1000 CFM corresponding to 400 ft/min face velocity with the standard 20 by 20 inch filters. By cutting the frames and filter elements the size of the net face area was reduced to 1 sq ft on two specimens. By means of a special adapter these filters could be tested without alteration of the test apparatus at 800 ft/min face velocity with an air flow rate of 800 CFM. Isokinetic air flow through the sampler tubes was used as previously described.

The filters tested were a Farr #4 and an Air-Maze Greastop. Fig. 4 and 5 show graphs of the efficiency plotted against the loading rate.

The efficiency of the filters appears to be best represented by a straight line on the semi-logarithmic paper as the curve of the least mean distances of the points of observation. The efficiency of the Air-Maze filter was found to be

GREASE FILTER TEST METHODS.




FILTER EFFICIENCY v/s LOADING RATE
at 800 ft/min FACE VELOCITY
Make: Farr #4
Loading Rate, g/hr
Effiency, percent
1
2
3
4
5
6
7
8
9
10
40
50
60
70
80
90
100
NBS
Fig. 4

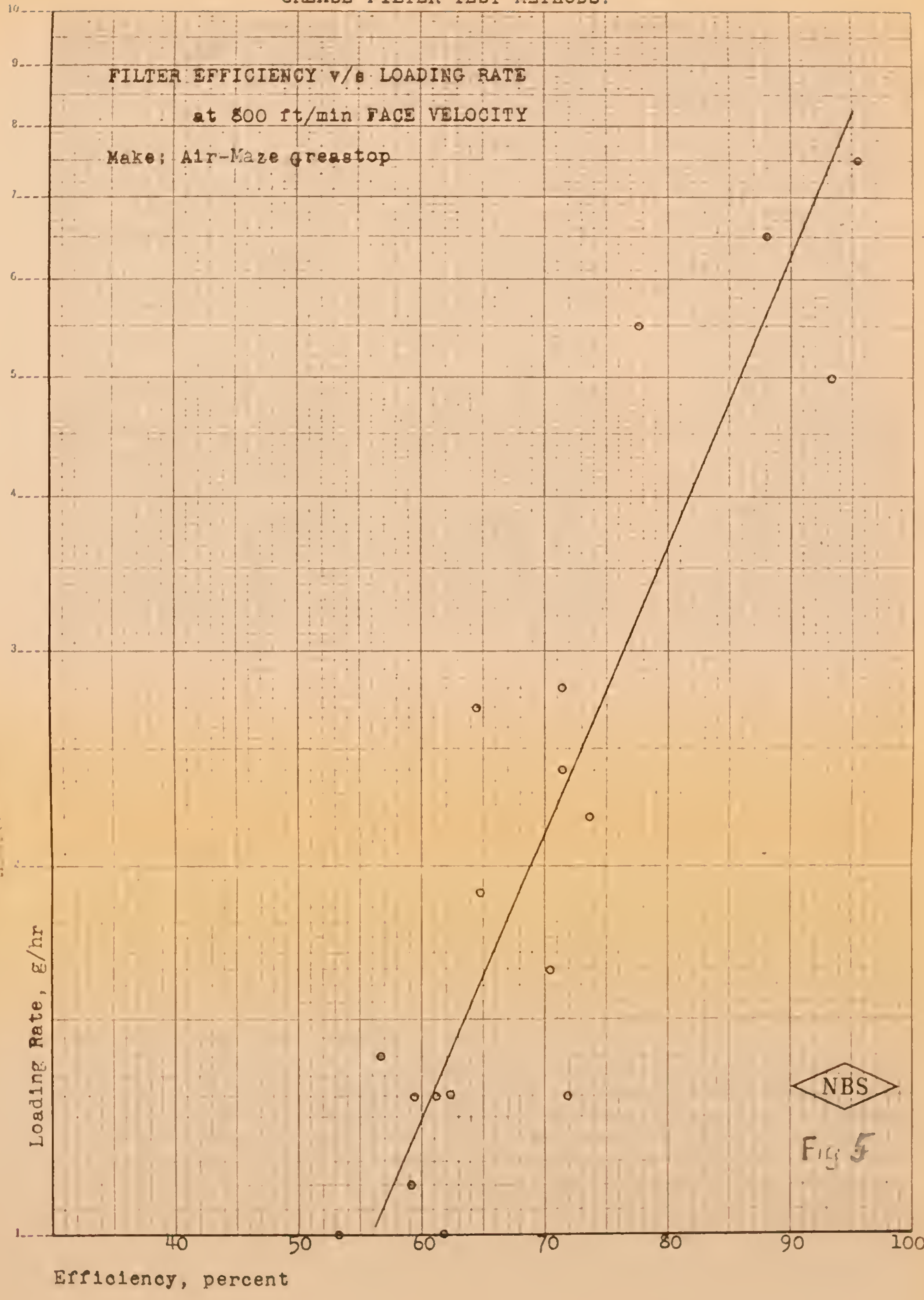

FILTER EFFICIENCY v/s LOADING RATE
at 800 ft/min FACE VELOCITY
Make: Air-Maze greastop
Loading Rate, g/hr
Efficiency, percent
1
2
3
4
5
6
7
8
9
10
40
50
60
70
80
90
100
NBS

Fig 5

slightly higher than that of the Farr filter, concurring with the observations made at 400 ft/min face velocity as reported in Progress Report No. 1772, dated July 8, 1952.

A comparison of the filter efficiencies observed during previous tests at 400 ft/min face velocity with those observed in the tests at 800 ft/min face velocity on the basis of equal loading rate per unit area requires consideration of the difference in filter sizes used in these tests. The net face area of the 20 x 20 in. filters used for determining the efficiency at 400 ft/min face velocity was 2.24 sq ft. Therefore, the efficiencies of these filters at a 10 g/hr loading rate must be compared with the efficiencies of the 1 sq ft filters used for the 800 ft/min face velocity tests at a loading rate of $\frac{10}{2.24} = 4.5$ g/hr.

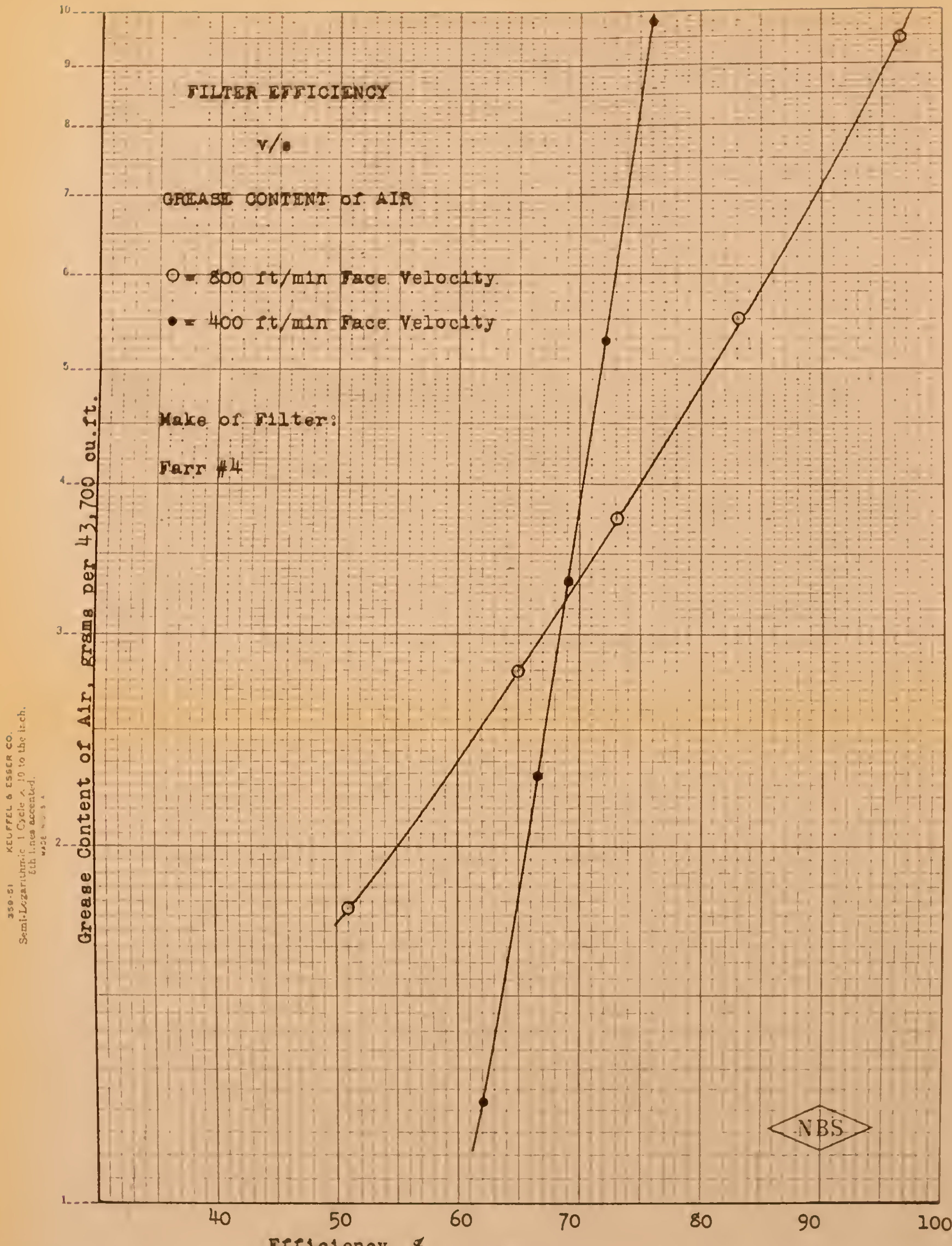
Based on the curves drawn through the plotted points the filter efficiency of the Farr filter tested at 800 ft/min face velocity at 4.5 g/hr loading rate was 81% and that of the Air-Maze 86%. Previous tests at 400 ft/min face velocity indicated that at 10 g/hr loading rate the corresponding efficiencies were 75% and 84%. The actual efficiency at a given loading rate cannot be stated with great precision because there was considerable scattering of the plotted values in Fig. 4 and 5 as well as in the corresponding data at lower face velocity. Deviations in efficiency of ±5% or greater were observed for the same loading rate.

A more informative comparison can be obtained of the difference in the efficiency of the filters operating at 400 and 800 ft/min face velocity by plotting the efficiencies against the grease contents of the air approaching the filters. The grease content of the air for a one hour period was determined by dividing the loading rate by the efficiency. The grease content of 100,000 cu ft was obtained by dividing the hourly grease content by the hourly flow rate through the filter and multiplying by 100,000. For convenient plotting on the available semi-logarithmic paper, the grease content was also calculated for 43,700 cu ft. The following table shows the values determined for the Farr #4 and Air-Maze Greastop filters. The values for the efficiency used in this table are the average values taken from Fig. 4 and Fig. 5 in this report and also from Fig. 1 and Fig. 2 of the July 9, 1952 progress report.

Relation of the Loading Rate, Filter Efficiency, and Grease Content of the Air at 400 and 800 ft/min Face Velocity.

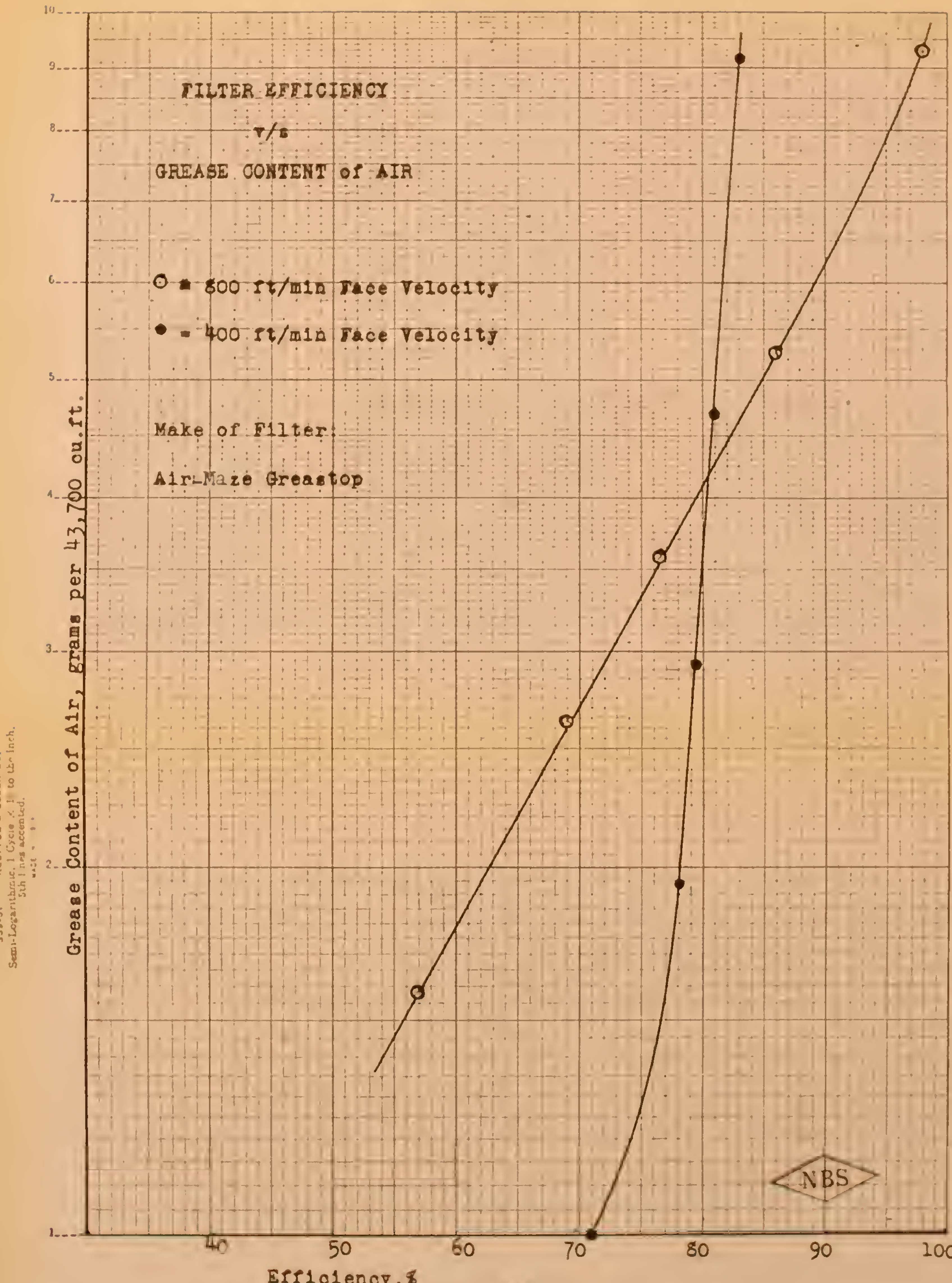
	400 ft/min Face Velocity					800 ft/min Face Velocity				
Loading Rate, g/hr	1	2	3	5	10	1	2	3	5	10
Farr #4										
Efficiency, %	62	66.5	69	72	76	51	65	73	83	96.5
Grease Content of Air, g/hr	1.61	3.01	4.35	6.94	13.17	1.96	3.08	4.11	6.03	10.37
" $g/10^5 ft^3$	2.80	5.23	7.56	12.06	22.87	4.09	6.42	8.58	12.68	21.61
" $g/43700\ ft^3$	1.22	2.29	3.31	5.27	9.98	1.79	2.81	3.75	5.50	9.44
Air-Maze Greastop										
Efficiency, %	76	78	79.5	81	83	57	69	76.5	86	98
Grease Content of Air, g/hr	1.32	2.56	3.76	6.16	12.05	1.75	2.90	3.93	5.80	10.20
" $g/10^5 ft^3$	2.29	4.45	6.54	10.70	20.91	3.65	6.05	8.20	12.10	21.26
" $g/43700\ ft^3$	1.00	1.94	2.85	4.68	9.15	1.59	2.64	3.58	5.28	9.30

Fig. 6 and 7 show graphs of the efficiency plotted against the grease content of the air approaching the Farr and Air-Maze filters, respectively. The graphs indicate that changes in the grease content of the air had a greater effect on the efficiency at 800 ft/min face velocity than it had at 400 ft/min. It will be noticed that for both filters the efficiency at 400 and 800 ft/min face velocity is equal at approximately 3 to 4 grams grease content per 43,700 cu ft of the air, at the intersection of the two curves. This corresponds to a loading rate of about 3 to 4 g/hr for the two filters. The curves also show that the efficiency at lower values of the grease content than 3 to 4



FILTER EFFICIENCY
v/s
GREASE CONTENT of AIR
O = 800 ft/min Face Velocity
• = 400 ft/min Face Velocity
Make of Filter:
Farr #4
Grease Content of Air, grams per 43,700 cu.ft.
Efficiency, %
10
9
8
7
6
5
4
3
2
1
40
50
60
70
80
90
100
NBS
KEUFFEL & ESSER CO.
Semi-Logarithmic 1 Cycle x 10 to the inch.
5th lines accented.

Fig. 6



FILTER EFFICIENCY
v/s
GREASE CONTENT of AIR
○ = 800 ft/min Face Velocity
● = 400 ft/min Face Velocity
Make of Filter:
Air-Maze Greastop
Grease Content of Air, grams per 43,700 cu.ft.
Efficiency,%
NBS
KEUFFEL & ESSER CO.

Fig. 7

grams per 43,700 cu ft of air is smaller at 800 ft/min face velocity than that at 400 ft/min face velocity and vice versa at higher grease contents.

The centrifugal forces caused by the changes of direction of the air passing the filter media throw air-borne grease particles from the air stream and make them adhere to the filter medium. The force acting to eject the grease particles from the air stream increases with the size of the particles and also with their velocity which in turn is a function of the face velocity at which the filter is being operated. The size of the particles will increase with the grease content of the air and change with the temperature of the grease, the length of time it has been heated and the type of the grease used. The analytical evaluation of the effect of these numerous variables on the efficiency of the filters appears extremely complex and not within the scope of these particular tests.

Paper Filters

The difficulty associated with proper cleaning of grease filters on board ships prompted an investigation of the feasibility of substituting expendable paper filters for the permanent impingement type filters. Out of a great number of commercial filter papers a group of four papers was selected which had a low flow resistance to air and promised good absorptivity for grease. The air flow rate through the clean filter papers obtained with a pressure drop of 2 in. W.G. across the paper was found to vary from 22 to 36 CFM per sq ft area. The flow rate was also determined after the filter papers were partially loaded with grease and it was found that the Eaton-Dikeman paper #640, which had the best characteristics, passed only 20.5 CFM per sq ft with a grease load of 0.1084 g per sq ft area at the same pressure drop of 2 in. W.G.

A pressure drop of 2 in. W.G. across the filtering medium was considered the maximum permissible for design purposes. Taking into account the possibility of increasing the area of the filter paper to ten times the face area of the filter, by arranging the paper in a zigzag pattern the total filter paper area that could be used in a 20 x 20 in. filter frame with a 2.24 sq ft face area would be 22.4 sq ft. With a load of 0.1084 g per sq ft this paper filter could hold a grease load of 0.1084 x 22.4 = 2.42 g and pass an air flow of 20.5 x 22.4 = 460 CFM, corresponding to a face

velocity of 205 ft per minute. At 400 ft/min face velocity the pressure drop across the filter paper would be near 8 in. W.G.

The measurements on board the U. S. S. Tarawa showed that loading rates of the filters ranged up to 92 g/hr or 38 times as much grease was retained by the impingement-type filter in an hour's cooking time as can be held by the filter paper at a lower than normal face velocity and a higher than desirable pressure drop.

This determination was considered to be adequate evidence that the method of abstracting grease from the cooking air by means of paper filters would not be practical.

Grease Deposits in Ducts

In order to obtain some information on the amount of grease deposited in a cold duct downstream of a filter the connecting duct between the grease filter test apparatus and the exhaust blower at the National Bureau of Standards was disassembled and inspected. This duct is 15 ft long and contains an orifice flow meter for measuring the air flow rate through the test filter. The diameter of this duct is 12 in. and the average air velocity is about 1200 ft/min. The duct had been in operation for 2-1/2 years, approximately 2500 hrs of testing without being cleaned when it was inspected. Grease accumulations were found on the bottom of the section containing the orifice plate and the two adjoining sections, whereas the upper parts and the sides of these three sections and all the other sections were practically clean.

Fig. 8 is a photograph of the duct section that holds the orifice plate, looking toward the test apparatus, i.e. upstream. The greatest depth of the grease accumulated on the bottom of the duct was approximately 3/8 in. downstream and 1/2 in. upstream of the orifice. Fig. 9 shows the section of duct adjacent to the orifice section in an upstream direction. It can be seen that the grease deposit on the bottom of this section extends to about 1/3 of its length. It appears from these photographs that the grease in the duct had been separated from the grease-laden air by the turbulence caused by the orifice plate and that it flowed off in both directions to the bottom of the ducts. The results of this inspection lead to the opinion that very little grease would have been deposited downstream of the filter in a smooth-flowing air stream of adequate velocity.

Fig. 8

Fig. 9

This assumption is supported by the fact that the guide vanes and the wheel of the exhaust blower had so little grease cover that no cleaning was required. There was no appreciable grease deposit in the bottom of the blower housing. The puddling of the grease shown in Fig. 8 and 9 indicates that the grease was warm enough to flow into the bottom of the duct during some periods of operation.

Further investigation appears desirable to ascertain the causes of grease deposits in ducts with and without a grease filter in the system with special attention given to the presence of lint in the air.

Water Cooled Filters

An Air-Maze Greastop filter was taken apart and 13 copper tubes, 1/4 in. O.D., were imbedded in alternate crimps of the filter screen near the middle of the 2 in. thick filter media. The copper tubes were extended through the filter frame and were manifolded in a 1 in. pipe on either end of the filter as shown in Fig. 10. City water at a temperature of about 55°F was passed through the tubes at a rate of 5 gal/min cooling the grease-laden air from 110°F to 106°F.

Eight tests of 7-1/2 hours each were made with this filter at loading rates ranging from 3.3 g/hr to 11.0 g/hr. The filtering efficiency in six of these tests was 34.3% ± 0.1% which compares rather unfavorably with an efficiency of about 80% determined for the same filter in an unaltered condition and at the same loading rate. The decrease in efficiency is believed to have been caused by spreading apart the filter media with the water tubes about midway through the filter media.

Fig. 11 is a photograph of a 16 x 16 x 3 inch cooling coil with three rows of tubes and six fins per inch that was tried out as a grease filter. The three coils were so manifolded that the water flowed through the coil in both directions to obtain a more equal cooling over the entire area. The coil was fitted into a wood frame, 20 x 20 in. outside, for convenient installation in the test apparatus. Because of the heavy weight of this coil it was considered impractical to determine the weight of the grease deposit by weighing the coil before and after each test. The efficiency was determined by installing sampling tubes upstream and downstream of the coil in the test apparatus. The filtering efficiency, then, was the difference between one and the ratio of the weight

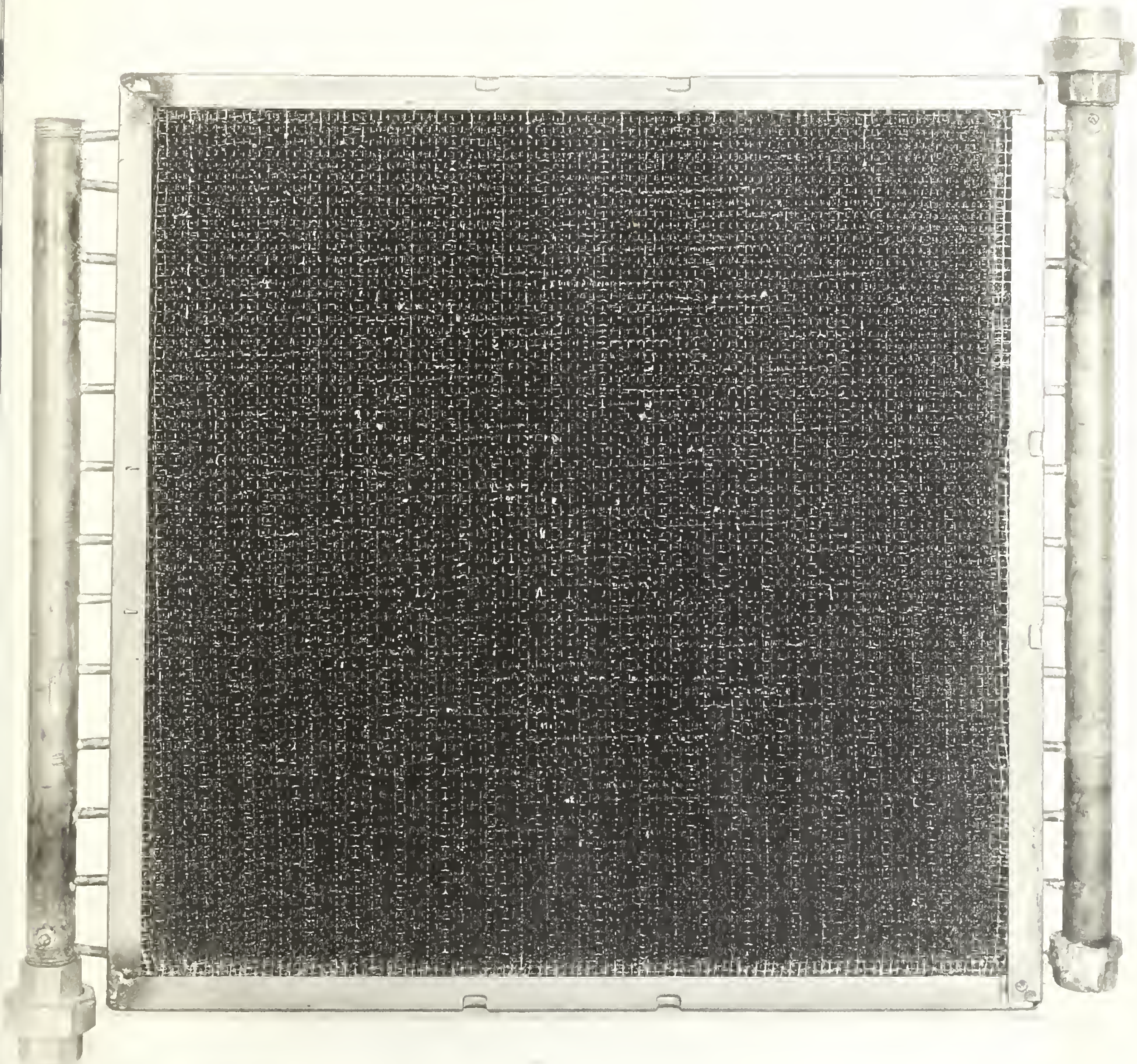


Fig. 10

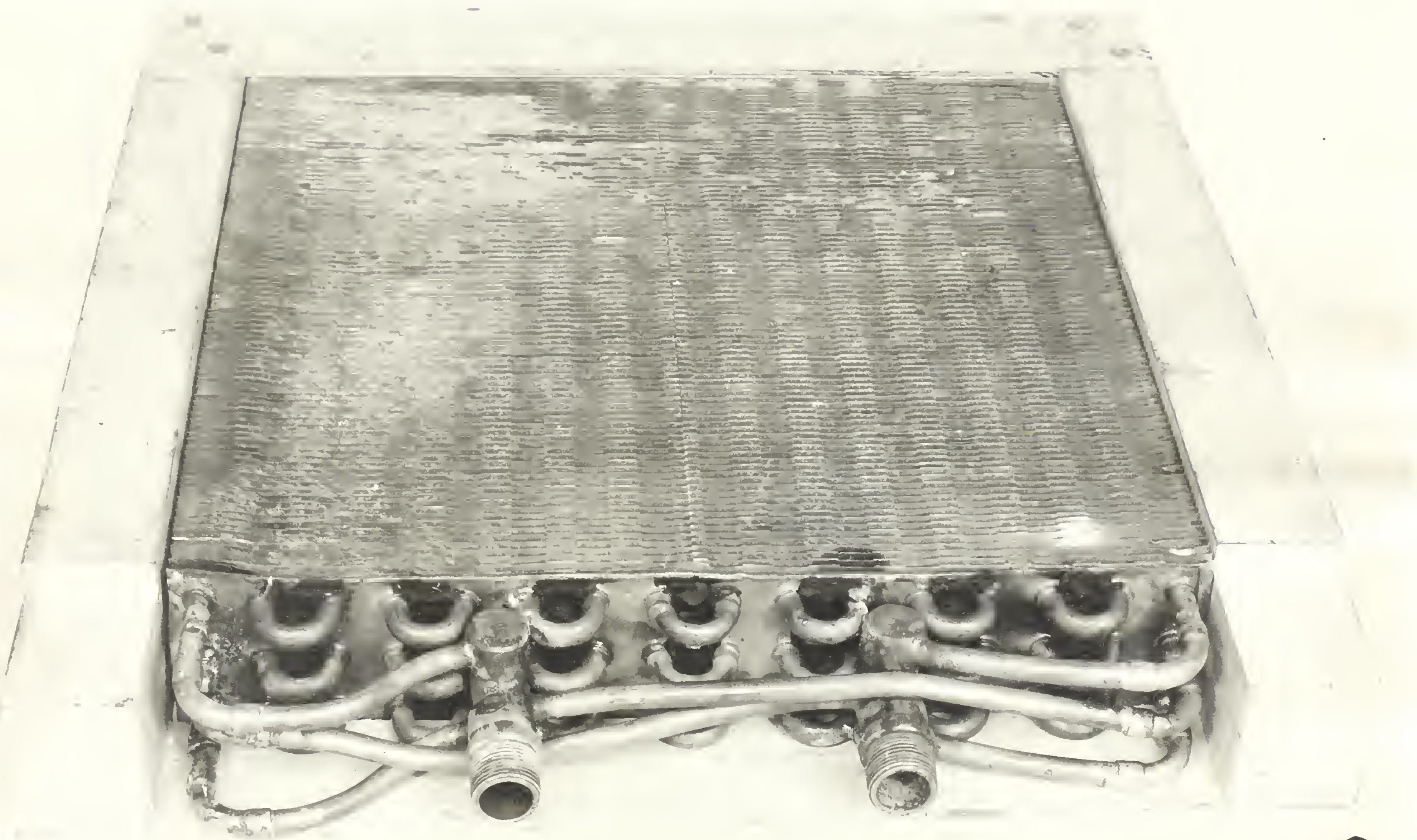


Fig. 11

increase of the sampler tube installed downstream (w_1) to that installed upstream of the coil (w_2).

$$\text{Efficiency} = (1 - \frac{w_1}{w_2})100 \text{ or}$$

$$E = \frac{w_2 - w_1}{w_2} \times 100\%.$$

The coil was operated for a total of 18 hours with water at a temperature of about 55°F flowing through it. The average efficiency was 62.8% at an average loading rate of 46 g/hr computed on the basis of a 20 x 20 in. filter.

A series of tests was then made to investigate the difference of the grease retaining ability of this coil when cooled with tap water and when it was not cooled.

For this purpose the grease filter test apparatus was operated under steady state condition and air samples were taken downstream of the coil during 1-1/2 hr periods alternately with water flowing through the coil and with the water shut off. Sufficient time was allowed for the coil to heat up or cool off before installing the new sampling tube in each cycle. It was found that the average weight increase of the downstream sampling tubes operated with a cooled coil was 5.8 mg and when the coil was at air temperature the weight increase was 7.5 mg, about 30% higher.

This test indicated that the retention of grease in the cooled coil was the result of both condensation of vapor and adhesion of liquid particles. In a coil or filter at ambient temperature very little condensation of grease vapor can occur because very little heat is transferred in the coil; therefore, only liquid particles can be retained.

Based on the experience gained in the above described test a filter has been built the filter medium of which consists of a stack of flat aluminum fins. Fig. 12 is a photograph of, this experimental model which has 475 fins of 0.001 in. and 60 fins of 0.002 in. thickness. Two gages of material were used as the thinner material was not available in sufficient quantity and could not be readily procured. The fins are separated from each other by five crimps, and the heavier material can be noticed on the right hand side of the photograph.

Two tests have been evaluated, to date, and showed an efficiency of 58% and 62%, respectively, at a loading rate of

Fig. 12

13.4 g/hr at 400 ft/min face velocity. The efficiency of the Air-Maze P-5 filter at the same condition was 67%.

The efficiency of this filter at various loading rates and its loading capacity will be further investigated. If these tests show satisfactory results, some modifications of the fin arrangement will be made to determine the optimum operational characteristics.

The advantage anticipated for a finned filter of this type would be that no cumulative clogging with lint would be likely between the filter faces such as occurs in wire mesh filters. These filters, if shown to have acceptable efficiency, should be easier to clean and last indefinitely.

The Gaylord Industries, Portland, Oregon, has advised us that they have shipped their ClearAir system here, for testing.

THE NATIONAL BUREAU OF STANDARDS

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